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# THE PERIODIC LAW OF ATOMIC NUCLEI: THE SPECIFIC NUCLEAR CHARGE AND THE PERIODIC SYSTEM OF ISOTOPES

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[Figures are appended]

(Russian editor's note: The material on which this article was based was presented by the author in the Academy of Sciences USSR in July 1947.)

This article represents a statement of part of the work presented on 28 July 1947 to the Committee on Inventions and Discoveries attached to the Council of Ministers USSR (certificate of authorship dated 28 July 1947).

Immediately after Ivanenko had established his neutron-proton model, Soviet authors (1) attempted to find a law governing the distribution of nucleons with respect to shells. Up to the present, however, authentic information on periodicities in the system of isotopic nuclei has not been found.

Moreover a new analysis of this problem has been stimulated by recent discoveries of many new isotopes and by accurate measurements of mass defects, spins, magnetic moments, etc.

In order to study regularities in nuclear properties, we adopt the simplest characteristic, namely the specific nuclear charge Z/A. The isotopes are shown in Figures 1 and 2, each characterized by coordinates Z/A and A. The graph which is obtained shows a number of regular variations in nuclear properties: it reveals the periodically varying structure and stability of nuclei, permits a conjecture on baryogenesis, and predicts undiscovered isotopes as well as type of radiation, values of nuclear spins, type of nuclear reactions, etc.



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In this report, Figure 1 includes the first period of the system of atomic nuclei up to Ca and Figure 2 includes the second period up to Sr. We noted these periodicities in 1947 while constructing a similar graph for all known elements up to $Z = 96$. Figure 2 shows clearly that the second period consists of two different sections, Ti - Zn and Ge - Sr. The periods Y - Ba and La - Ra behave similarly, while the latter is made more complex by the special lanthanum section.

Analysis of the graph as a whole indicates the existence of four periods of atomic nuclei which end in the nuclei of the alkali-earth metals Ca, Sr, Ba, Ra, and the fifth period, which ends for the time being at cirium, $Z = 96$.

This basic conclusion is confirmed by consideration of the curve showing the specific nuclear charge Z/A for the "main" isotopes of all elements of Mendeleyev's system (2); this curve is given for odd Z's in Figure 3. The "main" isotope is understood to be the nucleus contained in greatest amounts when the element was formed.

The hypothetical main isotopes were determined not only from previous data on the percentage of isotopic nuclei (3), but also from considerations of the conditions prevailing during the period of the formation of elements in the observable section of the universe and a number of secondary processes; determination of the main isotope from this set of factors causes real discrepancies between the abundance of nuclei of the main isotopes and the isotopes actually observed in the greatest abundance today. Isotopes of a system may in equal measure be "main" when making up 90 to 60 percent and, for example, 20 and 40 percent of the elements. Only in the first period up to Ca and in the first section (Sc - Zn) of the second period (Sc - Sr) do we have complete agreement of the main isotopes with isotopes which we now observe in the greatest quantity, with the exception of the known secondary $Ar^{40}$ (main isotope $Ar^{36}$), and also $N^{14}$ and $Ni^{58}$ (according to our hypothesis, the main isotopes are $N^{15}$ and $Ni^{60}$). Cases of disagreement of the main isotopes with isotopes of the greatest quantity are encountered more frequently in the third and fourth periods, since the nuclear structure of elements after Ga is made more complex by a greater number of secondary processes.

In Figures 1 and 2, the nuclei of stable isotopes are shown by points, the nuclei of main isotopes are shown by squares, and the nuclei of radioactive isotopes are denoted by the proper signs: $beta^-$, K, $beta^+$. All points on the vertical lines correspond to isobaric nuclei of a system, reflecting isobaric equilibrium in karyogenesis. The isotopic points of each element are connected by lines which prove to be hyperbolas. The nuclei of the elements of a system are placed in such a way that all nuclei having an isotopic number equal to zero ($j = A - 2Z = 0$) lie at a height $Z/A = 0.5$ above the A-axis.

All remaining nuclei lie on curves (called isotopic curves) for which the value of j, the isotopic number, is respectively: 1, 2, 3 etc or -1, -2, -3, etc.

The isotopic curves, which are hyperbolas, asymptotically approach the straight line $j = 0$ or $Z/A = 0.50$. The isotopic curves for the values $j = -1$, $j = -2$, etc., in Figures 1 and 2 describe nuclei in the region of positron emitters and are mirror images of the isotopic curves for $j = 1$, $j = 2$, etc. With the help of these curves the study of nuclei and their structure and stability and of the percentage content and abundance (Clarks) of isotopes will lead to a number of important conclusions.

The isotopic hyperbolas of Figure 1 which asymptotically approach the ordinate pass through the proton and neutron points which are genuine isobars and then go into the region of particles with mass less than unity. The curve for $j = 0$ is an isotopic curve of the main isotopes, that is, of nuclei of



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maximum stability of even Z's in the first structural period of atomic nuclei (up to Ca). The main isotopes (the most stable and most abundant nuclei) of the odd Z's are described, as a rule, by the curve for which $j_{odd} = j_{even} + 1$; for the first period by the curve $j = 1$. The nuclei of the elements ${}_4Be^9$ and ${}_7N^{14}$, which at first glance seem to violate this rule, actually confirm it, if the laws governing karyogenesis are considered. This will be described in another report. The specific charge of the most stable nuclei of elements of this period for even Z's is equal to 0.5; for odd Z's, it increases from ${}_3Li^7$ to ${}_{19}K^{39}$. The second period of the system Sc - Sr contains two sections: Ti - Zn and Ge - Sr. In the section Ti - Zn, the nuclei of the main isotopes are described, for even Z's, by the curve $j = 5$. In this section, the specific charge increases for nuclei of even and odd Z's (after a decrease at Sc). The section Ge - Sr has main isotopes of odd and even Z's for which $j_{Z+2} = j_Z + 2$, with a regular decrease in the specific nuclear charge.

The specific charge of atomic nuclei also changes regularly for the third and fourth periods of the system, as illustrated in Figure 3.

The curve for the main isotopes of odd Z's is shown, since they do not require special explanations, and the law of development on the Ga - Rb, In - Cs sections are undoubtedly expressed by the formula $j_{Z+2} = j_Z + 2$: $j_{Z+X} = j_Z + X$. The section Tl - Fr as a whole is also governed by the formula $j_{Fr} = j_{Tl} + 6 = 49$.

At the sections where the transition elements lie, the following succession of events occurs: an increase in the specific charge ($j = \text{const}$), stabilization, and, finally, gradual decrease.

The curve of Figure 3 shows that stable nuclei of all elements, without exception, lie within the comparatively narrow interval where the specific charge decreases from 0.5 (${}_2He^4$) to approximately 0.4 (Fr - 0.390, Ra - 0.389).

Further analysis of abundance, stability of spins, and other nuclear properties confirms the presence of periodicity, discovered by using the simplest criterion, namely, the specific nuclear charge.

The graphs of Figures 1 and 2 establish that the periodically alternating (through every single element) beta-negative and beta-positive activity is a function of the specific nuclear charge in each period. This permits a chemical element to be considered as a certain isotopic period in the development of a nuclear mass of given charge, having in view the successive formation of all heavier nuclei.

A study of the system shows that not only do the radioactive nuclei conform to a strictly periodic variation in stability and properties (beta-negative and beta-positive decay), but also the "stable" nuclei of elements change their properties periodically. The values of spins, effective cross sections of neutron reactions, lifetime, and other nuclear properties vary regularly along the isotopic curve in each period.

The periodically varying stability of isotopic nuclei with respect to beta and alpha decay varies within the limits of the permissible maximum and minimum of the specific charges which determine the stability of helium isotopes, and lies within the boundaries from 0.5 to approximately 0.4 of the absolute values of Z/A, where the entire system of elements exists.

The nuclei of all elements exist only within those limits of Z/A permitting the existence of the stable nucleus of ${}_2He^4$; the nuclei decay if these conditions are not observed. This fact is one of the proofs of the role of the alpha bond in the structure of heavy nuclei. The isotopic curves of Figure 1, as well as



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the similar curves for the remaining periods of the system of atomic nuclei, confirm the presence of alpha bonds. For all elements of any isotopic curve (for example, $j=1$), each successive nucleus of even or odd Z forms only by the addition of two protons and two neutrons, that is, the formation of an alpha "particle" or, more correctly, and alpha bond, since the binding energy of this structural component of heavy nuclei varies and drops toward the end of the system.

If we consider the conditions of genesis and the structure of our hypothetical main isotopes of the first period, we see (Figure 1) that any following nucleus of even or odd Z can be formed by an alpha bond. The main isotopes of odd elements $(Z+1)$ up to Ga are the result of the addition of a $_1H^3$ particle to the structure of the corresponding nucleus of even Z.

Thus, by analyzing our periodic system of atomic nuclei, we also approach from a new standpoint the fundamental importance of the alpha bond and free neutrons in the structure of complex atoms and show the dependence of the stability of the alpha bond upon the specific charge (volumetric and surface density of Z) and the number $j$.

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[Figures follow]



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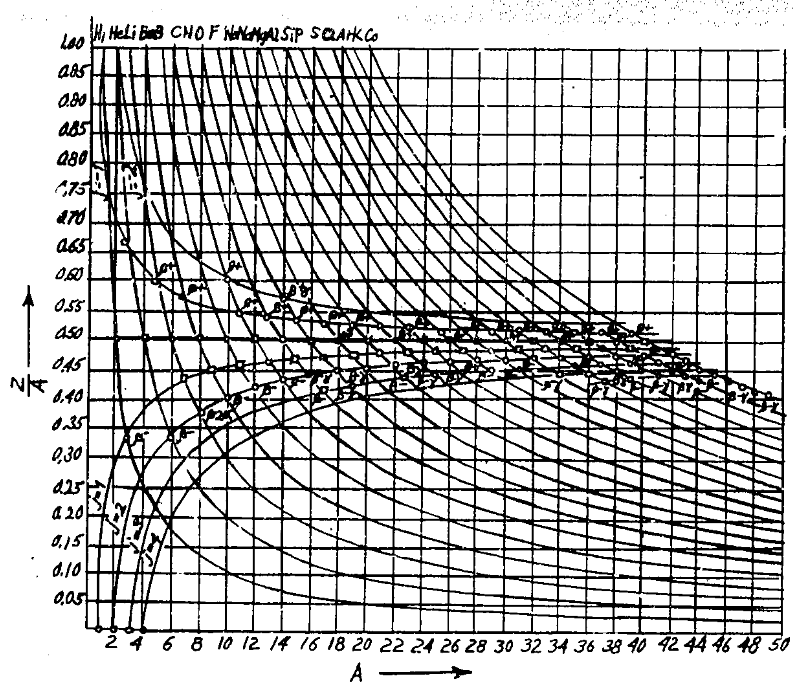
Figure 1



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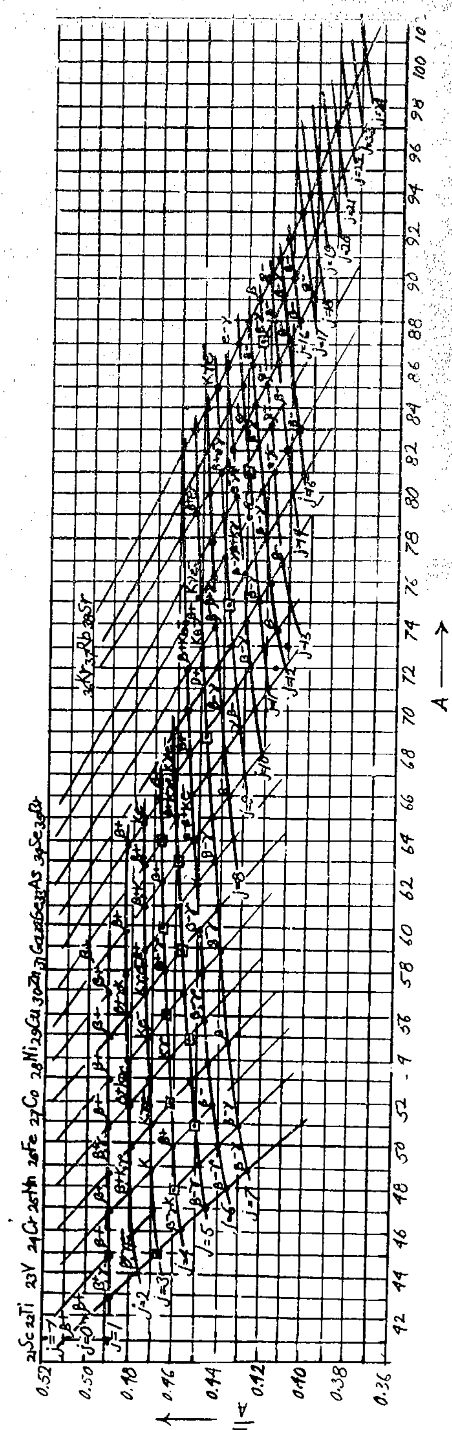

Figure 2

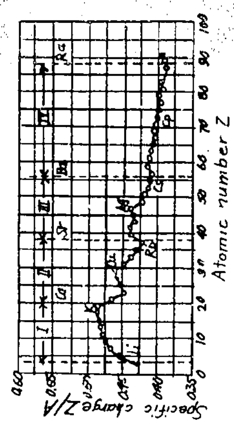


Figure 3

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